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אני, (שם המבקש, מענו ולגבי גוף מאוגד: מקום התאגדותו)
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Method and system for acoustic communication (באנגלית) (English)

Hereby apply for a patent to be granted to me in respect thereof.

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* בקשת חלוקה Application of Division	* בקשת פטנט מוסף Appl. for Patent of Addition	דרישת דין קדימה* Priority Claim		
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שיטה ומערכת לתקשורת אקוסטית

Method and system for acoustic communication

Medit - Medical Interactive Technologies Ltd

מדיט - טכנולוגיה רפואית אינטראקטיבית בע"מ

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METHOD AND SYSTEM FOR ACOUSTIC COMMUNICATION

FIELD OF THE INVENTION

This invention is generally in the field of communication techniques, and relates to a communication method and system utilizing acoustic signals.

BACKGROUND OF THE INVENTION

Acoustic computer communication techniques have been developed as an alternative to IR and RF wireless communication. Unlike IR and RF, sound does not have unexpected foes such as sunlight, rain, metal objects, and can be hidden from people if its frequency is higher than 20 kHz. IR usually requires direct visibility and is hampered by sunlight or bright interior light. Also, IR has such unexpected features as propagation through materials (that are not transparent in visible light) and reflection from various materials. RF suffers from interference problems and can be blocked by metallic objects.

Various advantageous features of the acoustic-based communication, as well as examples for protocols for acoustic transmission, are disclosed in the following article: "Things that talk: Using sound for device-to-device and device-to-human communication", V. Gerasimov and W. Bender, IBM Systems Journal, Vol. 39, Nos 384, 2000, pp. 530-546. It suggests using ultrasound for device-to-device communication and using audible signals when devices communicate to human listeners. A method for communicating with an electronic device utilizing acoustic transmission below 50kHz is disclosed in WO 00.21020 and WO 00/21203.

SUMMARY OF THE INVENTION

There is a need in the art to facilitate communication between various devices by means of data transmission in the form of acoustic signals to enable fast transmission with high signal to noise ratio, by providing a novel method and system for acoustic communication.

The main idea of the present invention consists of allowing for concurrently generating a modulated multi-frequency acoustic signal representative of the entire data sample (multi-bit data stream), and allowing for concurrently receiving and demodulating the entire data sample. This is implemented by using an array of acoustic transmitters and operating them to produce together a multi-frequency acoustic signal modulated in accordance with a data sample, and utilizing one or more acoustic receivers (preferably, at least two such receivers) for collecting a multi-frequency acoustic signal.

The present invention, according to its one broad aspect provides an acoustic transducer arrangement comprising:

(i) at least one input/output port for inputting/outputting a data stream in the form of at least one of the following signal formats: radio-frequency signal, infra-red signal, and electrical signal;

(ii) an acoustic transmitter assembly including an array of transmitter elements operable to generate together a multi-frequency acoustic signal;

(iii) an acoustic receiver assembly operable to receive a multi-frequency acoustic signal;

(iv) a control unit connected to the input/output port for receiving the data stream that is to be transmitted through the transmitter assembly as an acoustic signal and for outputting a data stream representative of the received multi-frequency acoustic signal, said processor assembly being preprogrammed to operate the acoustic transmitter assembly to generate the multi-frequency acoustic signal indicative of the received data stream, and to process data

representative of the received acoustic signal to demodulate it into an output data stream.

Each of the transmitter elements has a resonance frequency different from that of the other elements and is independently operated by the control unit to generate an acoustic wave component. The generated multi-frequency acoustic wave is thus a superposition of sinusoidal signals of the multiple different frequency components.

The resonance frequency of the transmitter element is preferably in a high ultrasound range, e.g., in a range of 1MHz-100MHz.

The number of the multiple different frequency components may be equal to the number of the transmitter elements in the array. Alternatively, the acoustic transmitter assembly may comprise at least one electrically conductive membrane accommodated in a path of the acoustic wave component generated by the transmitter element and operable to oscillate with a frequency different from that of said acoustic wave component. In this case, the number of said multiple different frequency components forming the acoustic signal is higher than the number of the transmitter elements in the array. One or more such electrically conductive membranes may be accommodated in the paths of all the acoustic wave components generated by the transmitter elements.

Preferably, the control unit is operable to modulate the data stream to be indicative of a network address of an associated communication station connectable to a communication network.

The acoustic signal may be frequency modulated in accordance with the data stream. For example, a presence of a specific frequency in the multi-frequency acoustic wave is indicative of binary "1" and absence of a specific frequency is indicative of binary "0". Alternatively, or additionally, the acoustic signal may be amplitude modulated.

According to another broad aspect of the present invention, there is provided an acoustic transducer arrangement comprising:

(i) at least one input/output port for inputting/outputting a data stream in the form of at least one of the following signal formats: radio-frequency signal, infra-red signal, and electrical signal;

(ii) an acoustic transmitter assembly comprising a piezoelectric element operable to generate an acoustic wave component corresponding to its resonance condition, and an electrically conductive membrane accommodated in a path of said acoustic wave component and operated to oscillate with a frequency different from the resonance frequency of the piezoelectric element;

(iii) an acoustic receiver assembly for receiving an acoustic signal;

(iv) a control unit connected to the input/output port for receiving the data stream that is to be transmitted through the transmitter assembly as an acoustic signal and for outputting a data stream representative of the received acoustic signal, said processor assembly being preprogrammed to operate the acoustic transmitter assembly to generate the two-frequency acoustic signal modulated in accordance with the received data stream, and to process data representative of the received acoustic signal to demodulate it into an output data stream.

According to yet another aspect of the present invention, there is provided an acoustic transmitter assembly for producing a multi-frequency acoustic signal, comprising at least one piezoelectric element operable to generate an acoustic wave component of a first frequency corresponding to the resonance frequency of the piezoelectric element, and an electrically conductive membrane accommodated in a path of said acoustic wave component and operable to oscillate with a second frequency different from the resonance frequency of the piezoelectric element, said multi-frequency acoustic signal being therefore a superposition of at least said first and second frequency components.

According to yet another aspect of the invention, there is provided a method for data exchange between first and second communication systems, the method comprising:

(i) receiving a signal representative of a digital data stream generated in the first communication system, and processing said data stream to translate it into a predetermined sequence of frequencies;

(ii) concurrently operating an array of acoustic transmitters to generate an acoustic signal in the form of a superposition of frequency components generated by the acoustic transmitters, respectively, and allowing transmission of said acoustic signal to the second communication system;

(iii) receiving a multi-frequency acoustic signal and processing it in accordance with data indicative of the predetermined sequence of frequencies to thereby reconstruct a data stream received from the second communication system.

The acoustic signals can be transferred between the first and second communication systems via a network formed by a plurality of acoustic transducer arrangements connectable to the network and configured for communicating with each other via the network. In this case, the digital data stream is also indicative of the network address of the respective acoustic transducer arrangement.

According to yet another aspect of the invention, there is provided a method for using in data communication between remote communication systems, the method comprising generating an acoustic signal representative of a modulated data stream, wherein said acoustic signal is a superposition of different frequency components in accordance with a predetermined sequence of frequencies.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to understand the invention and to see how it may be carried out in practice, a preferred embodiment will now be described, by way of non-limiting example only, with reference to the accompanying drawings, in which:

Figs. 1A and 1B schematically illustrate two examples of a communication technique according to the present invention;

Fig. 2 schematically illustrates the main functional elements of an acoustic transducer arrangement according to the invention;

Fig. 3 illustrates flow diagrams of the main operational steps of the generation of a modulated acoustic wave indicative of a data sample, and the demodulation of a received multi-frequency acoustic wave; and

Fig. 4 illustrates a specific example of the acoustic transducer arrangement according to the invention.

DETAILED DESCRIPTION OF THE INVENTION

Referring to **Fig. 1A**, there is schematically illustrated an acoustic communication system **10A** utilizing an acoustic transducer arrangement according to the invention. The system **10A** is composed of first and second communication systems **12** and **14** (such as computer-, phone-, PDA-based systems) each associated with its own acoustic transducer arrangement **16**, namely, is either connectable to the acoustic transducer arrangement via signal transmission or includes the acoustic arrangement as its constructional part. In the present example of Fig. 1A, the first and second systems **12** and **14** are equipped with the acoustic transducer arrangements **16A** and **16B**, respectively.

The acoustic transducer arrangement is configured as a chip with an embedded application preprogrammed for both transmission of encoded acoustic data signals, and receiving and decoding acoustic data signals. When operating in the transmission mode, the acoustic transducer arrangement operates to receive an input electrical, IR, RF or acoustic data stream carrying signal produced by the respective communication device, and process it to generate an output encoded data carrying acoustic signal. When operating in the receiving mode, the acoustic transducer arrangement **16** is capable of receiving an encoded acoustic data

carrying signal and processing it to generate a decoded electrical, IR, RF or acoustic data signal to be used for the device operation. The construction and operation of the acoustic transducer arrangement will be described further below with reference to Fig. 2.

Referring to Fig. 1B, there is exemplified an acoustic communication system 10B utilizing the acoustic transducer arrangements according to the invention. The system 10B presents a communication network, and comprises various communication stations 12, 14A-14D connectable to each other via a communication network 16 formed by an array of acoustic transducer arrangements. Generally, each of the communication stations can be configured as a server system capable of producing various data streams and appropriately distributing (routing) them in between the other stations, and being responsive to data signals coming from the other stations via network. In the present example of Fig. 1B, the station 12 is exemplified as a server-like station, and the stations 14A-14D are exemplified as client-like stations. It should be understood that the terms *"server"* and *"client"* used herein solely refer to the existence and absence of a router utility in the station. It should also be understood that each of the communication stations may comprise its associated acoustic transducer arrangement as a constructional part, or be connectable to a stand-alone acoustic transducer arrangement.

In the example of Fig. 1B, the communication station 12 is configured as a computer system that is equipped with a data generating and processing utility (not shown) and a router utility 12A, which is in turn equipped with or connected to the acoustic transducer arrangement 16A. The communication stations 14A-14D are constituted by, respectively, a medical measuring device (e.g., ECG), PDA device, mobile phone device, and a PC device. These devices 14A-14D may and may not be equipped with the acoustic transducer arrangements. For example, the PC 14D is equipped with the acoustic transducer arrangement 16D, and the other devices have no integral acoustic transducers and receive electrical, RF or IR signals (as the case

may be, typically RF) presenting a conversion of the acoustic data signal from the associated remote acoustic transducer arrangement.

The system 10B operates in the following manner. The computer system 12 (its data generating/processing utility) generates a digital data stream to be transmitted to a specific communication device, e.g., the ECG station 14A, via the communication network. The router utility 12A performs appropriate formatting of this data stream to be addressed to the specific communication device via corresponding one or more nodes of the network The acoustic transducer arrangement 16A, which is a node of the network 16, receives the formatted data stream, converts it into an encoded acoustic signal and allows the transmission of this signal via the network 16.

It should be understood that the router is preprogrammed to utilize an appropriate hash table representative of network addresses of the transducer arrangements forming the network 16 along with their associated names, and preferably also utilizes a segmentation map representative of a list of this IDs and names attached with the last known segment ID. The segmentation process thus consists of the following: the router that has previously transmitted a message to a specific segment ID, waits for a notification from the transmitting element indicative of that the specific network address along with the associated name corresponds to that segment, and if not, the router retransmits the message to all the segments. In the example of Fig. 1B, where the acoustic network 16 is utilized, each acoustic transducer arrangement is assigned with its unique identification code (network address) and these IDs are used for routing the data streams in between the communication stations. In this specific example, each of the acoustic transducer arrangements is preferably preprogrammed to identify the incoming signal to either process it as described above or just allowing the signal to be appropriately distributed to another acoustic transducer arrangement or the communication station.

Reference is now made to Fig. 2 schematically illustrating the construction of an acoustic transducer arrangement, generally designated 116, according to the invention. The transducer arrangement 116 is designed like an electronic card (chip with embedded application) comprising an acoustic transmitter assembly 20, an acoustic receiver assembly 22, a control unit 24 that is connectable to the transmitter and receiver assemblies and to a network interface unit 26. The network interface unit 26 includes one or more signal input/output ports – three such ports P_1-P_3 being shown in the present example configured for inputting/outputting RF, IR, and electrical signals, respectively.

The transmitter assembly 20 is composed of an array of acoustic transmitters (e.g., piezoelectric crystal elements) - four such transmitters 20A-20D being shown in the present example, operable by the control unit 24 via an oscillation generator and voltage supply assembly 21. According to the technique of the present invention, the operational frequencies of the acoustic arrangement are of the ultrasound range, preferably high ultrasound range, higher than 1MHz, e.g., of about 1-100MHz. The receiver assembly 22 comprises one or more acoustic receivers (e.g., piezoelectric crystals) - two such receivers 22A and 22B being shown in the present example. The received acoustic data is transmitted to the control unit 24 via a frequency filter arrangement 23, which includes a "static" filter that blocks frequencies below the selected ultrasound range, and, in the case of more than one receiver, includes also a frequency sub-divider unit.

The known piezoelectric phenomenon consists of converting a mechanical deformation into a voltage, and the counter piezoelectric phenomenon consists of converting a voltage into a mechanical deformation. The piezoelectric element is typically formed by a substrate of a piezoelectric material (quartz resonator) that is preferably very thin (of about several micrometers) to enable the generation of high frequency acoustic waves, and electrodes on opposite faces of the substrate. The electrodes are connected to a high-frequency voltage source, which operates

through the electrodes to cause the lengthwise vibration in the piezoelectric substrate.

The present invention provides for combining several piezoelectric crystal elements 20A-20D together to concurrently produce a wide-range multi-frequency acoustic signal, and to enable modulation of these frequencies (i.e., perform a signal encoding) in accordance with a data stream to be transmitted. This enables simultaneous transmission of multiple frequency components indicative of a multi-bit data stream sample (formed by one or more words), rather than bit-by-bit transmitting a data sample using a single transmitter element. Since in order to generate an acoustic wave of a specific frequency by a piezoelectric crystal, the voltage supply is to satisfy the resonance condition of the crystal, the higher the number of crystals in the transmitting array, the more frequencies can be concurrently generated. As for the receiver assembly 22, generally, the provision of one receiver would be sufficient, but preferably at least two such receivers (i.e., receiver array) are used allowing detection of a wide range of acoustic wave frequencies and concurrent decoding of the entire received sample. It should, however, be understood that since the acoustic signal detection is not limited by the resonance condition of the crystal, the receiver array may include a smaller number of crystal elements than the transmitter array.

The control unit 24 includes a memory (RAM), a microprocessor that is connected to the oscillation generator 21 and to filter arrangement 23 via a logic utility and a clock utility. Also provided in the transducer arrangement 116 are such functional utilities as an D/A-A/D converter, and amplifiers for amplifying the input signal to be converted into an encoded acoustic signal and amplifying the electrical signal representative of the received acoustic signal.

The operational steps of the acoustic transducer arrangement 116 will now be described with reference to Fig. 3. In the data transmission mode, the acoustic transducer arrangement 116 operates as follows. The control unit 24 receives a digital data stream from one of the input utilities (or the router or directly from the

data generation utility of a computer device, as the case may be). The digital data stream is stored in an appropriate format, and is sliced into samples that are of a predefined fixed length (e.g., 4 or 8 bits in a sample). For example, 106 Hexadecimal values can be used, each Hexadecimal value being representative of 4 bits, thus having 53 samples. The control unit 24 operates together with the clock and logic utilities to generate a corresponding sequence of voltages in accordance with the predefined order of the transmitters' frequencies in the array and then operate the oscillation generator 21 accordingly to provide the respective voltage-sample. The oscillation generator 21 thus operates the transmitters 20A-20D via their electrode assemblies to simultaneously produce acoustic signal components representative of the data sample. To this end, each of the transmitters is responsible for generating an acoustic wave of a predefined frequency (corresponding to its resonance condition), and preferably also predetermined amplitude, as will be described further below.

The multiple-transmitter assembly 20 (crystal elements 20A-20D) is thus operable to concurrently produce a multi-frequency acoustic wave indicative of a data sample to be transmitted. As will be described further below with reference to Fig. 4, a two-frequency acoustic wave can be achieved with a single crystal.

In the receiving mode, the transducer arrangement 116 operates as follows. The acoustic receiving element (22A and 22B) always "listens" for incoming signals, i.e., are continuously responsive to incoming acoustic signals to cause the generation of respective voltage outputs. As the incoming signals generated by the acoustic transducer arrangement of the present invention are in a specific, very high range of acoustic frequencies, a simple high pass band filtering can be used. Thus, the voltage output of the receivers undergoes high-pass frequency filtering (i.e., voltages corresponding to frequencies outside the predetermined range, e.g., lower than the predetermined range, are prevented from being detected) and the sub division in accordance with the frequency ranges of the receivers. Then, the filtered signal is processed: the acoustic signal is sampled from the piezoelectric crystals

and stored in a Pulse Code Modulation (PCM) wave format, which is practically the voltage representation of the sampled crystals, and the data sample can therefore be stored in a RAM unit. The logic utility thus identifies the timing of the incoming frequencies, and operates together with the microprocessor to store the voltage values in the RAM.

Then, the microprocessor operates to apply the Fast Fourier Transform (FFT) to the stored voltage series. The result of the FFT is the frequency map indicative of which frequency represents digital "0" and "1" values. The microprocessor analyzes the frequency map and performs an error correction to restore (decode) the received signals. Having decoded the received signal, the control unit 24 actuates the selective port to transmit the signal to a respective communication device in the form of RF, IR or electrical signal. The case may be such that while decoding the first received signal, the microprocessor identifies that the signal is addressed to another acoustic arrangement of the network (i.e., identifies the network address of the specific acoustic arrangement appearing in the first received sample). In this case, the control unit will operate the transmitter assembly 20 accordingly to retransmit the received signal in the acoustic form via the network.

The use of multi-frequency acoustic waves based communication (multi-frequency transmission at a given time) enables frequency modulation or frequency and amplitude modulation of the acoustic signal to be indicative of the entire data sample. This features of the acoustic transducer arrangement of the present invention allows for its advantageous use in device-to-device communication, as compared to the proposed prior art technique (utilizing a single pair of acoustic transmitter and receiver) and to the conventionally used electromagnetic waves based communication where only one frequency can be received (and therefore broadcasted) at a given time (limited by a tuning problem). Another advantageous feature of the technique of the present invention is the operation with high-frequency acoustic waves and specific signal modulation (as exemplified above and

as will be exemplified further below), which requires much less sophisticated noise-filtering techniques, as compared to the known communication techniques.

Thus, in the transmission operational mode, the control unit operates to apply a frequency coding to the acoustic signal, such that the generated acoustic signal is a superposition of sinusoidal signals of multiple frequency components indicative of a multi-bit data stream sample. In the receiving operation mode of the transducer arrangement, the control unit processes the electrical outputs of the receiver(s) (22A and 22B in Fig. 2) to concurrently decode the received multi-frequency coded multi-bit data sample by applying a time-to-frequency domain transformation (Fourier transform) thereto, thereby obtaining a multi-bit spread spectrum. This spectrum is analyzed, preferably using an error correction, to identify the predetermined frequencies within the received sample and translate the sample into a digital data stream.

The encoding of the multi-frequency acoustic wave indicative of a data sample may consist of the following. The first transmitter in the array (transmitter 20A) is operable to generate the so-called "basic frequency", e.g., f_1=1MHz, and all the other transmitters 20B-20D generate frequencies spaced from the basic frequency a predefined spacing, e.g., f_2=1.0001MHz, f_3=1.0002MHz, f_4=1.0003MHz, respectively. The existence or absence of the specific frequency in the transmitted frequency-sample is indicative of respectively logic "1" or "0". It should be understood that this is a specific example of the number of transmitters in the array and the frequency values and spacings between them. Using a higher number of transmitters enables concurrently transmitting a larger data sample. Thus, a wave-form signal is created by concurrently transmitting all the four frequencies during a predefined fixed time length (for example 200 milliseconds). For example, the 4-bit word "1001" (data sample) can be transmitted by concurrently generating frequencies f_1-f_4 at amplitudes A_1=90, A_2=0, A_3=0, A_4=90. The data sample may also be amplitude modulated. This modulation may be based on a predefined ranges for amplitudes A_1-A_4, and/or a specific key, e.g., the sum of

amplitudes of 1st and 3rd bits and 2nd and 4th bits in the sample, or an amplitude difference between the adjacent frequencies in the received frequency stream. In other words, the amplitudes of the existing frequencies can be varied in a certain predefined order, known to the receiver. For example, the amplitude difference being higher than a certain predefined threshold is considered as corresponding to "1", and the amplitude difference being lower than the threshold is considered as corresponding to "0". While decoding (demodulating) the received signal, the appropriate error correction is carried out. Considering the simple amplitude modulation of the acoustic signal, the error correction can be based on checking for the amplitudes order in the received signal, or a certain threshold for an amplitude difference between the adjacent frequencies in the received frequency stream.

The following is a specific, non-limiting example, of encoding the acoustic signal to concurrently transmit a data sample in the form of two 4-bit words, and an error correction performed while decoding the received signals. In this specific example, four-element transmitter assembly is considered, and the operational (resonance) frequencies of four crystal resonators are f_1=1MHz, f_2=1.0001MHz, f_3=1.0002MHz, and f_4=1.0003MHz, respectively. Thus, the signal encoding utilizes the specific order of frequencies f_1, f_2, f_3, f_4 in the four-frequency acoustic signal. Additionally, in order to enable concurrent transmission of the entire data sample formed by two 4-bit words, the acoustic signal is amplitude modulated. The amplitudes used for transmitting the frequencies f_1- f_4 are for example as follows: $0<A_1<30$; $30<A_2<60$; $60<A_3<90$; $90<A_4<127$. In order to enable error correction at the receiving side, a certain key is used, for example "0101010...".

Let us consider the transmission of 4-bit words W_1 = 1000, W_2=1010, W_3=1001, W_4=0001, W_5=0010 and W_6=1001, wherein two 4-bit words W_1 and W_2 present the first data sample to be concurrently transmitted by four crystal resonators, two 4-bit words W_3 and W_4 present the second data sample, and two 4-bit words W_5 and W_6 present the third data sample. When transmitting the first data sample, four crystal resonators generate acoustic signals representative of symbols

"11", "00", "01" and "00", respectively. The position of each symbol in the sample is represented by the respective frequency in accordance to the predefined order of frequencies. According to the selected key, symbol "11" when appearing for the first time or for the first time after transmission of symbol "00" is represented by the maximal value of amplitude A_4, i.e., 127, and a further appearing of this symbol prior to "00" is represented by any other value of A_4 range, preferably the center point of the range. Consequently, symbol "00" is represented either by the minimal value of amplitude A_1, i.e., zero (when appearing for the first time after symbol "11"), or by any other value of A_1 range (preferably, the center point of this range). Symbols "01" and "10" are represented by amplitudes A_2 and A_3, respectively, preferably at the center values of the selected ranges. Thus, in this specific example, the multi-frequency acoustic signal representative of six 4-bit words contains three sequentially generated data samples, wherein each sample is concurrently generated as a four-frequency acoustic signal: (f_1=127, f_2=0, f_3=45, f_4=15), (f_1=65, f_2=15, f_3=15, f_4=127), (f_1=45, f_2=0, f_3=75, f_4=45). At the receiver side, this acoustic signal is translated using the above key, and upon detecting an error (no correspondence with the key), the respective sample is identified and transmitted back with a request for retransmitting the sample again.

Another possible example of signal encoding/decoding consists of using second harmonics of each frequency in the sequence. In this case, the resonance frequency of each transmitter (crystal resonator) is selected to be other than the second harmonic of another resonator frequency. Thus, alternatively to the above-described amplitude modulation or in addition thereto, the second harmonic of each resonant frequency may be used as a key for encoding the signal and carrying out the error correction.

As indicated above, a transmitter in the multi-transmitter assembly can generate a two-frequency acoustic wave while utilizing a single crystal resonator. This is schematically illustrated in Fig. 4, showing an acoustic transducer arrangement 116 having a transmitter assembly 120 equipped with at least one

electrically conductive membrane **M** (thin electrode) associated with one or more crystal elements in the array. In the present example of Fig. 4, the membrane (or four separate membrane segments) is provided at the output of all the crystal resonators. If the membrane is in its inoperative position (no voltage is applied to the membrane), a single-frequency acoustic wave generated by the respective crystal resonator propagates through the membrane while being unaffected by the membrane. If the membrane is shifted to its operative position by applying a certain voltage thereto, this results in a membrane vibration with a certain frequency (typically slightly different from the resonance frequency of the respective crystal element). The passage of a single-frequency acoustic wave generated by this crystal element through the operative membrane will result in a two-frequency acoustic wave. Thus, eight-frequency acoustic wave (8-bit data sample) can be produced by four-crystal array with membrane. If appropriate amplitude modulation is used, for example that described above, 16-bit data sample can be generated by the four-transmitter assembly with membrane.

Those skilled in the art will readily appreciate that various modifications and changes can be applied to the embodiments of the invention as herein before exemplified as defined in and by the appended claims.

CLAIMS:

1. An acoustic transducer arrangement comprising:

(i) at least one input/output port for inputting/outputting a data stream in the form of at least one of the following signal formats: radio-frequency signal, infra-red signal, and electrical signal;

(ii) an acoustic transmitter assembly including an array of transmitter elements operable to generate together a multi-frequency acoustic signal;

(iii) an acoustic receiver assembly operable to receive a multi-frequency acoustic signal;

(iv) a control unit connected to the input/output port for receiving the data stream that is to be transmitted through the transmitter assembly as an acoustic signal and for outputting a data stream representative of the received multi-frequency acoustic signal, said processor assembly being preprogrammed to operate the acoustic transmitter assembly to generate the multi-frequency acoustic signal indicative of the received data stream, and to process data representative of the received acoustic signal to demodulate it into an output data stream.

2. The acoustic transducer arrangement of Claim 1, wherein each of the transmitter elements of the transmitter assembly has a resonance frequency different from that of the other elements and is independently operated by the control unit to generate an acoustic wave component, the generated multi-frequency acoustic signal being a superposition of sinusoidal signals of the multiple different frequency components.

3. The acoustic transducer arrangement of Claim 1 or 2, wherein the resonance frequency of the transmitter element is higher than 1MHz.

4. The acoustic transducer arrangement of Claim 1 or 2, wherein the resonance frequency of the transmitter element is in a range of 1MHz-100MHz.

5. The acoustic transducer arrangement of Claim 2, wherein the number of said multiple different frequency components is equal to the number of the transmitter elements in the array.

6. The acoustic transducer arrangement of Claim 2, wherein the acoustic transmitter assembly comprises at least one electrically conductive membrane accommodated in a path of the acoustic wave component generated by the transmitter element and operable to oscillate with a frequency different from that of said acoustic wave component, the number of said multiple different frequency components forming the acoustic signal being thereby higher than the number of the transmitter elements in the array.

7. The acoustic transducer arrangement of Claim 6, wherein said at least one electrically conductive membrane is accommodated in the paths of all the acoustic wave components generated by the transmitter elements.

8. The acoustic transducer arrangement of any one of preceding Claims, wherein the acoustic receiver assembly comprises at least two acoustic receivers.

9. The acoustic transducer arrangement of any one of preceding Claims, wherein the control unit is operable to modulate the data stream to be indicative of a network address of an associated communication station connectable to a communication network.

10. The acoustic transducer arrangement of any one of preceding Claims, wherein the control unit is operable to frequency modulate the acoustic signal, such that a presence of a specific one of frequency components in the multi-frequency acoustic signal is indicative of binary "1" and absence of a specific frequency component is indicative of binary "0".

11. The acoustic transducer arrangement of any one of preceding Claims, wherein the control unit is operable to apply an amplitude modulation to the frequency components.

12. An acoustic transducer arrangement comprising:

(i) at least one input/output port for inputting/outputting a data stream in the form of at least one of the following signal formats: radio-frequency signal, infra-red signal, and electrical signal;

(ii) an acoustic transmitter assembly comprising a piezoelectric element operable to generate an acoustic wave component corresponding to its resonance condition, and an electrically conductive membrane accommodated in a path of said acoustic wave component and operated to oscillate with a frequency different from the resonance frequency of the piezoelectric element;

(iii) an acoustic receiver assembly for receiving an acoustic signal;

(iv) a processor assembly connected to the input/output port for receiving the data stream that is to be transmitted through the transmitter assembly as an acoustic signal and for outputting a data stream representative of the received acoustic signal, said processor assembly being preprogrammed to operate the acoustic transmitter assembly to generate the two-frequency acoustic signal modulated in accordance with the received data stream, and to process data representative of the received acoustic signal to demodulate it into an output data stream.

13. An acoustic transmitter assembly for producing a multi-frequency acoustic signal, comprising at least one piezoelectric element operable to generate an acoustic wave component of a first frequency corresponding to the resonance frequency of the piezoelectric element, and an electrically conductive membrane accommodated in a path of said acoustic wave component and operable to oscillate with a second frequency different from the resonance frequency of the piezoelectric element, said multi-frequency acoustic signal being therefore a superposition of at least said first and second frequency components.

14. A communication device connectable to a communication network, the device comprising the acoustic transducer arrangement of Claim 1.

15. A communication system comprising at least two communication devices connectable to each other through at least one acoustic transducer arrangement of Claim 1.

16. A method for data exchange between first and second communication systems, the method comprising:

(i) receiving a signal representative of a digital data stream generated in the first communication system, and processing said data stream to translate it into a predetermined sequence of frequencies;

(ii) concurrently operating an array of acoustic transmitters to generate an acoustic signal in the form of a superposition of frequency components generated by the acoustic transmitters, respectively, and allowing transmission of said acoustic signal to the second communication system;

(iii) receiving a multi-frequency acoustic signal and processing it in accordance with data indicative of the predetermined sequence of frequencies to thereby reconstruct a data stream received from the second communication system.

17. The method of claim 16, wherein the received signal representative of the data stream is in the form of at least one of the following signal formats: radio-frequency signal, infra-red signal, and electrical signal.

18. The method of Claim 16, wherein said acoustic signal is transferred to the second communication system via a network formed by a plurality of acoustic transducer arrangements communicatable with each other.

19. The method of Claim 18, wherein the digital data stream is indicative of the network address of the respective acoustic transducer arrangement.

20. The method of Claim 16, wherein each of said frequencies is higher than 1MHz.

21. The method of Claim 16, wherein each of said frequencies is in a range of 1MHz-100MHz.

22. The method of Claim 16, wherein said processing of the data stream comprising assigning to each of the frequencies a certain amplitude in accordance with predefined amplitude ranges for said frequencies.

23. A method for using in data communication between remote communication devices, the method comprising generating an acoustic signal representative of a modulated data stream, wherein said acoustic signal is a superposition of different frequency components in accordance with a predetermined sequence of frequencies.

24. A method for using in data communication between remote communication devices, the method comprising generating an acoustic signal representative of a modulated data stream, wherein said acoustic signal is a superposition of different frequency components of higher than 1MHz, thereby reducing a noise component associated with reflections of said acoustic signal.

For the Applicants,
REINHOLD COHN AND PARTNERS
By:

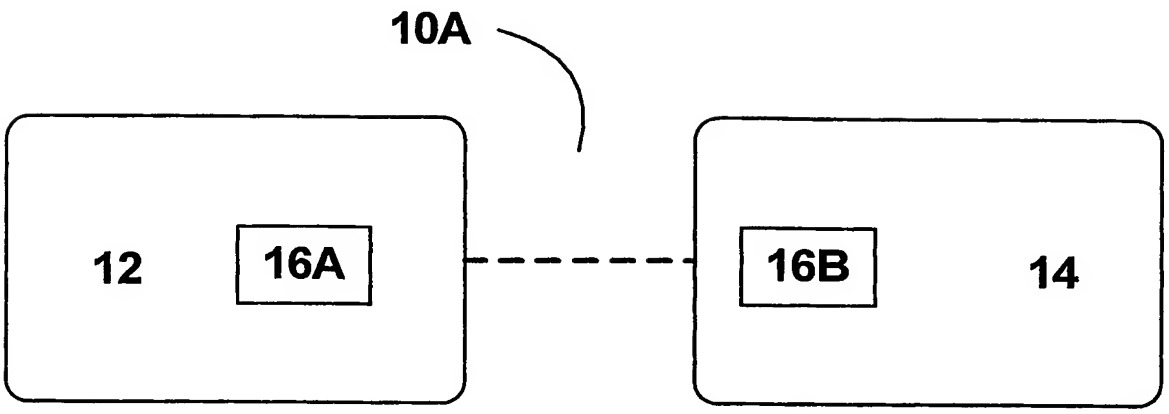

Fig 1A

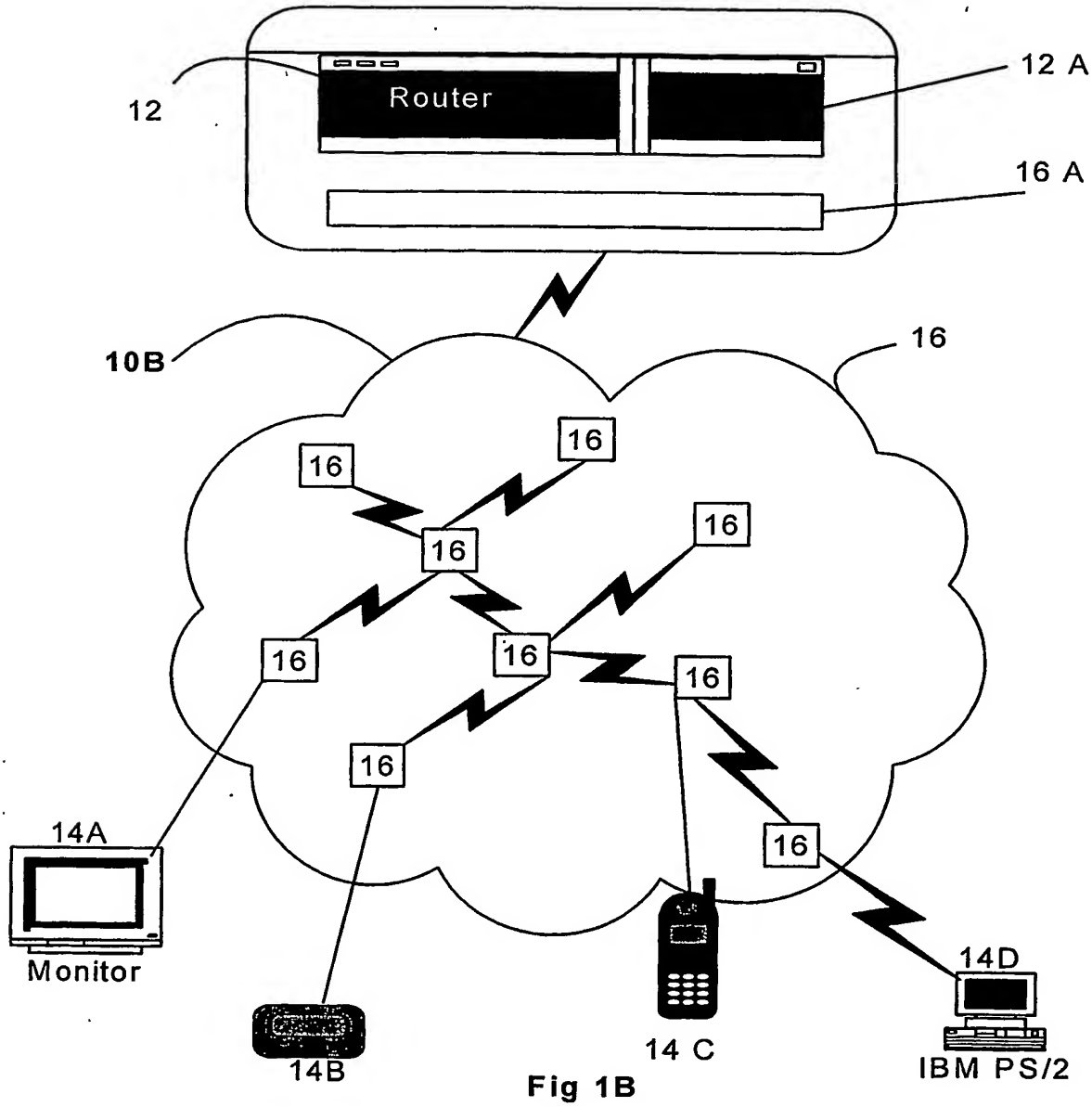
12
Router
12 A
16 A
10B
16
16
16
16
16
16
16
16
16
16
14A
Monitor
14B
14 C
14D
IBM PS/2

Fig 1B

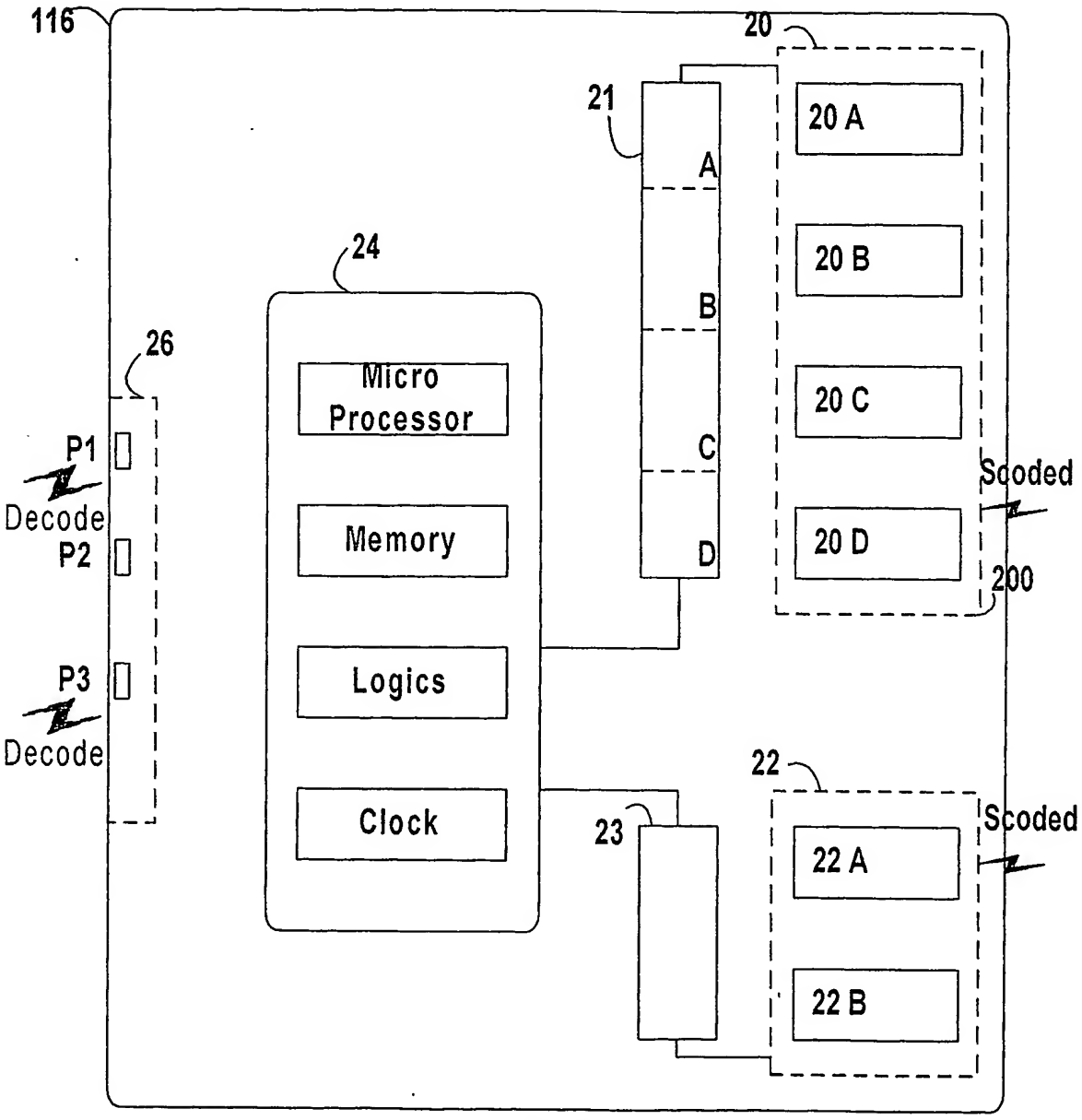
116
20
21
20 A
A
20 B
B
24
Micro Processor
20 C
C
26
P1
Decode
P2
Memory
20 D
D
Scoded
200
P3
Decode
Logics
Clock
22
23
Scoded
22 A
22 B

Fig 2

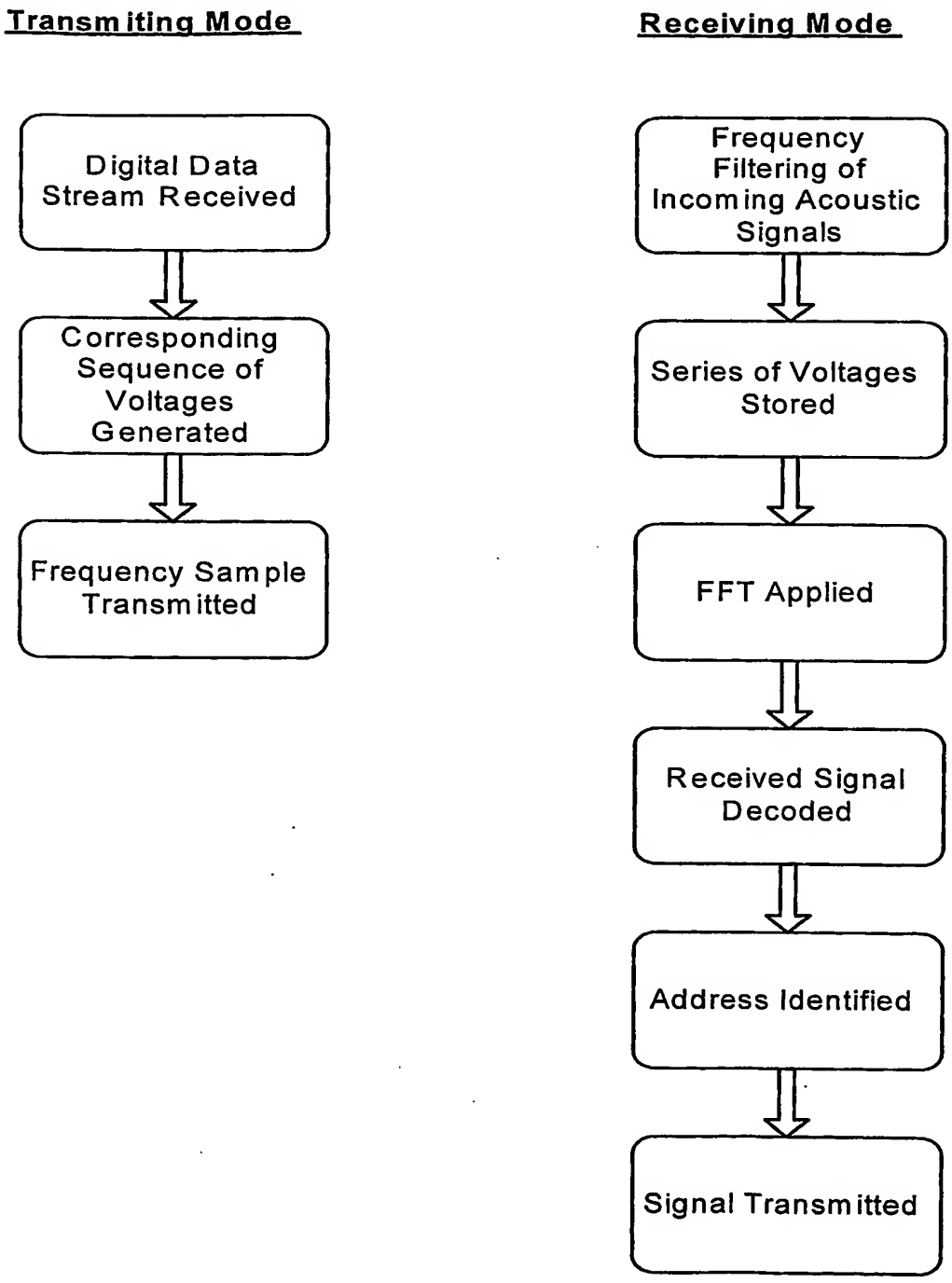
Transmiting Mode
Digital Data Stream Received
Corresponding Sequence of Voltages Generated
Frequency Sample Transmitted
Receiving Mode
Frequency Filtering of Incoming Acoustic Signals
Series of Voltages Stored
FFT Applied
Received Signal Decoded
Address Identified
Signal Transmitted

Fig 3

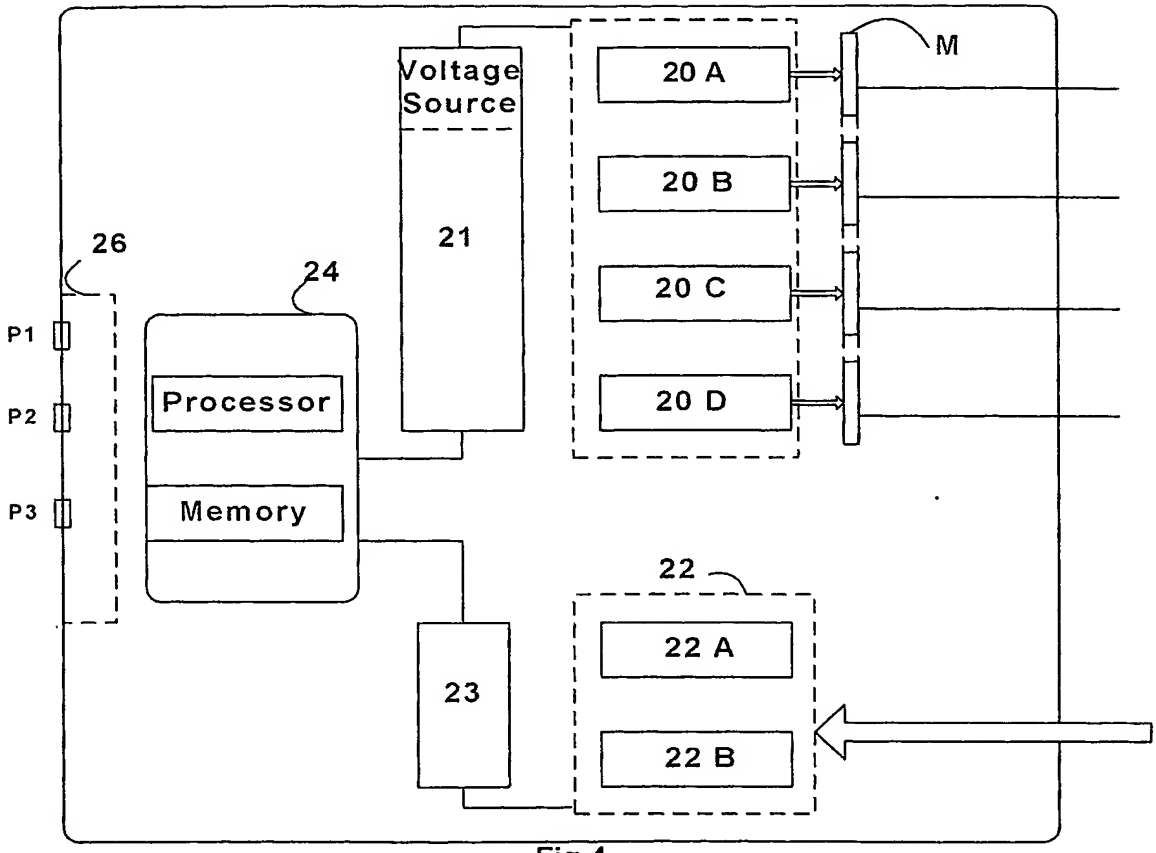
Voltage Source
21
20 A
20 B
20 C
20 D
M
26
24
P1
P2
P3
Processor
Memory
22
22 A
22 B
23

Fig 4